

# Making Actinometer Paper

by Edward Grabczewski

## Introduction

I have compiled several methods for preparing **actinometer paper** for use in photographic **actinometers** (a type of exposure meter) of the late nineteenth and early twentieth centuries. Examples include the cylindrical **Watkins** (1891) *Standard Exposure Meter* and the **Wynne** (1893) “*Infallible*” *Hunter Meter*, which resembled a pocket watch. Since *actinometer paper* is no longer manufactured commercially, it must now be prepared by hand.

A **printing-out paper** (POP) is a photographic paper that produces a visible image simply by exposure to light, without requiring chemical development. This made it ideal for use in photographic actinometers, since the photographer could observe the paper darkening and stop the exposure when it matched a standard reference tint. By contrast, a **developing-out paper** (DOP) forms only a *latent image* during exposure. Although this image is initially invisible, it can be revealed by subsequent chemical development.

## History

The measurement of *actinic* light by means of sensitised materials has a long history. W. H. F. Talbot noted the idea of an actinometer as early as March 1840 as a means of determining printing times, and a number of experimental devices based on the darkening of silver chloride paper appeared during the following decades. Bunsen and Roscoe (1858–1862) subsequently demonstrated that the darkening of silver chloride paper could be used to measure the chemical action of light quantitatively and established a standard comparison tint for actinometric measurements. Swan (1866) adapted these principles to photographic exposure determination, while later commercial actinometers, often known as **tint-meters** (so called because exposure was judged by matching the darkened paper to a standard tint), were developed by manufacturers such as Watkins and Wynne for everyday photographic use.

**Eder** (1891) observed that actinometry measures the *chemically active* component of light rather than its apparent *visual brightness*. He further noted that the chemical action of light depends upon the spectral sensitivity of the substance employed, so that, strictly speaking, there are as many actinometric scales as there are light-sensitive materials. Nevertheless, **Bunsen and Roscoe** (1863) showed that the indications of the chlorine-hydrogen actinometer and the silver-chloride paper actinometer correspond sufficiently well for practical purposes.

Contemporary writers recognised that more than one type of actinometer paper was in use. Early actinometers, such as those described by Bunsen and Roscoe and **Swan** (1866), employed silver-chloride printing-out paper, which darkens directly when exposed to light. Bunsen and Roscoe demonstrated experimentally that equal shades of blackness correspond to equal products of light intensity and exposure time, establishing the quantitative principle underlying later photographic actinometers. By the 1880s, however, bromide-based actinometer papers had begun to appear. Stanley and Sarjeant (1886) described sensitive paper prepared from a bromide salt “instead of the usual chlorine salt”, indicating a departure from the earlier silver-chloride papers. **Wall** (1889) likewise noted that ordinary silver-chloride printing-out paper could still be used for actinometric purposes, but regarded it as unsuitable for determining the exposure of bromide emulsions. He therefore recommended preparing actinometer paper from gelatino-bromide paper treated with potassium nitrite.

Writing in 1930, **Clerc** (1930) similarly noted that many actinometer papers employed silver bromide or silver iodide emulsions chemically sensitized with substances such as sodium nitrite or tannin. Although differing in composition, these papers were all intended to produce a visible printing-out image without development and thus functioned as printing-out papers. The methods collected below span this transition from early silver-chloride printing-out papers to later sensitized bromide and iodide papers.

The use of potassium nitrite to prepare actinometer paper was well established by the late nineteenth century. **Harrison** (1892) reported that bromide paper treated with a 10 per cent solution of potassium nitrite formed "an excellent actinometer" and would attain its deepest indigo-blue colour in twenty-five seconds in strong sunlight. **Tennant** (1911) later described a similar process and reported the same *actinometer time* of twenty-five seconds. The agreement between these independently published accounts, separated by almost twenty years, provides strong evidence for the consistency of potassium-nitrite-sensitised bromide papers used for actinometric purposes.

Many of the methods described in the literature employ bromide paper, which was widely used for photographic printing at the time. Traditional bromide papers of the type available in the late nineteenth century are no longer manufactured, although expired boxes can occasionally be obtained. Modern photographic papers may also prove suitable, but their greater sensitivity may require additional filtering, reduced illumination, or other measures to obtain suitably long actinometer times. It should also be noted that *modern* bromide papers are generally much thicker than the narrow strips used in some Watkins actinometers. Consequently, experimental papers may need to be exposed in a separate light-tight holder rather than within the original instrument itself.

## Plate Speed

**Plate speed** is a numerical expression of the *sensitivity* of a photographic plate. "Faster" plates require less exposure and permit the use of smaller apertures or shorter exposure times than "slower" plates.

## Making the paper

The following methods for preparing *actinometer paper* have been described in the literature:

### A. Early Silver-Chloride Actinometer Papers

#### Method 1: Bunsen & Roscoe (1863)

1. Immerse good-quality writing paper for 5 minutes in a 3% solution of sodium chloride.
2. Remove and dry the paper.
3. Float the paper for 2 minutes on a solution of silver nitrate (120 g per litre of water).
4. Dry the paper in darkness.

The resulting "standard paper" is coated with silver chloride and darkens directly on exposure to light.

#### Method 2: Swan (1866)

- Immerse plain photographic paper for 10 minutes in 2% solution of chloride of sodium [sodium chloride], and then float for 2 minutes upon an 8% solution of nitrate of silver [silver nitrate].

## B. Later Sensitized Bromide Actinometer Papers

### Method 3: Stanley and Sarjeant (1886)

- Use sensitive paper prepared from a bromide salt instead of the chlorine salt commonly employed in earlier actinometer papers. The exact bromide compound used is not specified, although potassium bromide is a plausible candidate.

### Method 4: Wall (1889)

1. Soak a strip of gelatino-bromide paper in a 2% solution of nitrate of potash [potassium nitrate].
2. Let the paper dry (in the dark).

The historical term "potash" derives from "pot ash", which consisted largely of potassium carbonate ( $K_2CO_3$ ). However, nineteenth-century chemists often used "potash" in compound names to denote potassium. Thus "nitrate of potash" is the historical name for potassium nitrate ( $KNO_3$ ).

### Method 5: Watkins (1891)

- Take a piece of sensitive bromide paper (treated with potassium nitrite).

### Method 6: Maskell (1911)

1. Soak a piece of bromide paper in a 10% solution of potassium nitrate (in yellow light).
2. Let the paper dry (in the dark).

### Method 7: Tennant (1911)

1. Procure some *slow* bromide paper.
2. Immerse each sheet for 5 minutes in 10% solution (45 grains [2.9 grams] to each fluid ounce [28.3 grams] of water) of potassium nitrite (not nitrate).
3. Do this in weak light or gaslight.
4. Dry the paper in darkness.
5. Strong sunlight turns the paper indigo blue in twenty-five seconds.

### Method 8: Wall (1924)

- Bromide paper should be immersed in the darkroom for 5 minutes in a 2.5 to 5 per cent solution of potassium metabisulphite or sodium nitrite, rinsed and dried [in the dark].

It is noteworthy that some authors specify potassium *nitrate* while others specify potassium *nitrite*. Whether this reflects differing formulations, differing terminology, or transcription errors remains uncertain.

**Note:** Methods 3–8 assume the availability of bromide paper. Readers wishing to prepare bromide paper from raw materials are referred to the companion paper [Making Bromide Paper](#) (Grabczewski, Internet Archive, 2026).

## C. Modern Reconstructions

The following methods are offered as practical modern reconstructions using either homemade bromide paper or commercially available photographic paper.

### **Method 9:** Actinometer Paper from Homemade Bromide Paper

This method assumes that bromide paper has already been prepared, for example, using one of the methods described in the companion paper [Making Bromide Paper](#).

1. Obtain a sheet of bromide paper.
2. Immerse the paper for 5 minutes in a 10% solution of potassium nitrite (10 g potassium nitrite in 100 mL distilled water).
3. Remove the paper and allow it to dry completely in darkness.
4. Cut the paper into strips suitable for use in an actinometer.

#### **Notes**

This method follows the general approach described by Watkins (1891), Harrison (1892) and Tennant (1911), all of whom employed potassium-nitrite-treated bromide paper for actinometric purposes. Harrison and Tennant reported that such papers attained a deep indigo-blue colour in approximately twenty-five seconds in strong sunlight.

### **Method 10:** Actinometer Paper from Modern Silver-Gelatine Photographic Paper

This method assumes that a commercially manufactured silver-gelatine photographic paper is being used.

1. Obtain a sheet of silver-gelatine photographic paper.
2. Under safelight conditions, immerse the paper for 5 minutes in a 10% solution of potassium nitrite (10 g potassium nitrite in 100 mL distilled water).
3. Remove the paper and allow it to dry completely in darkness.
4. Cut the paper into strips suitable for use in an actinometer.

#### **Notes**

Modern photographic papers are generally more sensitive than nineteenth-century bromide papers. Consequently, they may darken more rapidly than historical actinometer papers and may require adjustment of the potassium-nitrite concentration, the illumination reaching the paper, or the calibration standard in order to obtain convenient actinometer times.

Both resin-coated (RC) and fibre-based (FB) photographic papers may be used. Older or expired papers may provide behaviour closer to that of the slower bromide papers available during the late nineteenth century.

## Calibrating actinometer paper

Each method given below will require the paper to be calibrated. When exposed to light, the paper darkens. The shade is compared to that of a proprietary reference tint (an 18% grey card may provide a convenient modern approximation).

In photographic actinometers, the exact colour (or *hue*) of the darkened paper is generally less important than its degree of darkness (or *shade*). The paper is compared with a proprietary reference *tint*, and exposure is judged primarily by matching the *shade* rather than the *hue*. Blue glass was optionally used in the *Watkins Standard Exposure Meter* to help remove the *hue* and focus only on the *shade* itself.

When *calibrating* the paper, expose it to a *standard* amount of light and see what *shade* it produces. Then use watercolour paints to reproduce this *shade* on a card, which can be mounted next to the paper to act as a reference. Time the number of seconds or minutes it takes for the paper to match the reference *shade*. This is called the *actinometer time*.

### Watkins' Speed

Early Watkins actinometers employed a simple calibration standard, described in **Watkins (1918)** as follows:

“The standard of plate speed (Watkins) is that speed **1** is such that with f/8 in midday June sunlight the plate is correctly exposed in two seconds – the same as the *actinometer time*.”

Note that in this definition, a plate speed of Watkins "**1**" is defined as when the *actinometer time* equals the plate *exposure time*. If “midday June sunlight” is not accessible then the following definition can be substituted:

“two grains [ $\approx 0.13$  grams] of magnesium ribbon burnt as a spiral coil at a distance of  $4\frac{3}{4}$  inches [ $\approx 12.1$  cm] from the sensitive paper”.

When reproducing the magnesium ribbon standard experimentally using a Sekonic L-508 light meter, approximately 3600 lux was measured at the paper position. Since lux measures *visible* light rather than actinic light, this should be treated as a practical modern reference rather than an exact equivalent of the original photographic standard. Therefore, as a practical approximation, suitably calibrated actinometer paper exposed to actinic light under similar conditions might be expected to darken to the standard shade in about 2 seconds.

### Wynne's Speed

Watkins introduced his plate-speed standard in 1890. According to **Watkins (1906)**, Wynne's original speed standard was identical to the Watkins standard, but was later modified by redesignating Watkins **1** as Wynne **F8** and adopting a distinctive **F-number** classification. Under this system, plate sensitivity was expressed as the **F-number** at which an *average* subject could be correctly exposed in the *actinometer time*. Consequently, faster plates were assigned larger **F-numbers**, such as **F45**, **F64**, **F90** and **F128**, since a *more* sensitive plate could produce a correct exposure through a *smaller* aperture.

Although Wynne's scale subsequently diverged from the Watkins system, Watkins recorded that Wynne **F45** was equivalent to Watkins **45**.

## References

- Bunsen, R. W., and H. E. Roscoe. *Photochemical Researches. Part V. On the Measurement of the Chemical Action of Direct and Diffuse Sunlight*. Philosophical Transactions of the Royal Society of London, Vol. 153, 1863, pp. 139–160.
- Clerc, L. P. *Photography: Theory and Practice*. London: Chapman & Hall, 1930, p. 207.
- Eder, Josef Maria. *Ausführliches Handbuch der Photographie*. Vol. I, Part 2. *Die Photometrie der chemisch wirksamen Strahlen und die Prüfung der Empfindlichkeit photographischer Präparate*. 2nd edition. Halle a. S.: Wilhelm Knapp, 1891.
- Harrison, W. Jerome. *The Chemistry of Photography*. New York: The Scovill & Adams Company, 1892.
- Maskell, H. P. *Photography*. London, 1911.
- Stanley, W. F., and W. L. Sarjeant. *Actinometers for Photography*. [British Patent No. 4624, 1886](#).
- Swan, J. W. *The Photographic News*, Vol. 10, 16 March 1866, p. 124.
- Tennant, J. A. *Photography at Home*. London, 1911.
- Wall, E. J. *The Dictionary of Photography*. New York, 1889.
- Wall, E. J. *Photographic Facts and Formulas*. New York, 1924.
- Watkins, A. *The Watkins Manual*, 1906 3rd ed., p.120; 1919 8th ed., p.125.
- Watkins, A. *Photography*. London, 1918, p. 55.
- Watkins, A. *Standard Exposure Meter*. [British Patent No. 1388, 1890](#). [U.S. Patent No. 456,869, 1891](#).
- Wynne, G. F. *"Infallible" Hunter Meter*. [British Patent No. 10,617, 1893](#).
- Wynne, G. F. *Latest List of Plate Speeds For Use With Wynne's "Infallible" Exposure Meter*, 1937.

## Appendix

### Understanding Watkins' Speeds

A photographic actinometer was an early form of light meter. It contained a strip of sensitised paper that darkened when exposed to sunlight. The photographer exposed the paper and timed how long it took to reach a standard shade. This was known as the *actinometer time* and was then used to calculate the camera *exposure time*.

In the Watkins system, plate speed **1** was defined as a plate requiring a correct exposure of 2 seconds at f/8 in bright *midday June* sunshine. Under these conditions, the actinometer was designed to indicate *2 seconds*. Thus, for a Watkins **1** plate, the *exposure time* was equal to the *actinometer time*. The choice of *midday June* sunlight provided a convenient and reasonably reproducible reference condition before modern standards of light measurement existed.

The Watkins system was deliberately simple. Exposure was calculated as:

$$\text{Exposure Time} = \text{Actinometer Time} \div \text{Watkins Plate Speed}$$

for *average* outdoor subjects.

For example, if the *actinometer time* is 8 seconds:

| Actinometer Time | Watkins Plate Speed | Exposure Time |
|------------------|---------------------|---------------|
| 8 sec            | 1                   | 8 sec         |
| 8 sec            | 2                   | 4 sec         |
| 8 sec            | 4                   | 2 sec         |
| 8 sec            | 8                   | 1 sec         |

Thus, a Watkins **2** plate required half the exposure of a Watkins **1** plate, while a Watkins **4** plate required one quarter of the exposure.

Direct conversion between Watkins and modern ISO speeds is not possible because the systems were defined using different standards. However, Watkins **1** was an extremely slow speed by modern standards. Wynne's later redesignation of Watkins **1** as **F8** implies a U.S. speed of approximately 4 according to **Wynne's** 1937 speed tables, suggesting that Watkins **1** may have corresponded to a speed of the order of ISO 4. Any comparison between Watkins, Wynne and modern ISO speeds should be regarded as approximate, since these systems were defined using different methods.

The Watkins system's popularity lay in its elegance: once the *actinometer time* was known, the *plate speed* itself acted as the divisor needed to calculate the correct *exposure time*.

### Understanding Wynne's Speeds

Wynne expressed plate speed as the f-number at which the plate would produce a correct exposure in the time measured by the actinometer. Thus, for a given *actinometer time*, the **F-number** assigned to a plate represented the aperture required for an *average* subject.

For example, with a measured *actinometer time* of 2 seconds, an **F90** plate would require an aperture of f/90, while an **F64** plate would require an aperture of f/64. Because f/90 admits less light than f/64 for the same exposure time, an **F90** plate must be *more* photographically sensitive than an **F64** plate.

## Colour terminology

In colour theory, *hue*, *tint*, *shade*, and *tone* describe different aspects of a colour.

A *hue* is the basic colour itself—such as red, blue, green, or yellow—without regard to how light, dark, bright, or muted it may be. A *tint* is created by adding white to a *hue*, making it lighter. A *shade* is created by adding black to a *hue*, making it darker. A *tone* is created by adding grey (or reducing *saturation*), making the colour less vivid and more subdued. For example, bright blue is a *hue*; pale blue is a *tint*; navy blue is a *shade*; and slate blue is a *tone*.

In the context of photographic actinometers, the *hue* refers to the actual colour of the darkened paper (blue, violet, brown, etc.), while the *tone* or *shade* refers to its degree of darkness. Since actinometers were intended to measure light intensity rather than colour, the exact *hue* was usually less important than achieving the correct *tone* or *shade* when compared with the *reference tint*.